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PROGRESS REPORT NO. 2

CONTRACT NO. RD-53-SA

Research Order #1R&D4

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INTRODUCTION

This is the second progress report to be submitted on this project. It describes the work done on a pulse modulation system. A unit using pulse amplitude modulation was investigated as a means of communication with a view toward security and efficiency. The design and testing of the units on a system basis is discussed.

DISCUSSION

The following are some of the design considerations taken into account during the development of the circuits.

Pulse amplitude modulation concists of a process wherein the amplitude of a pulse carrier, is varied in accordance with the value of an audio modulating wave.

The Nyquist criterion for sampling a signal states that in order to determine uniquely the value of the sampled wave at all times, the minimum sampling rate required is two pulse samples per audio cycle. This equipment was designed on a more conservative basis, in which the ratio of pulse repetition rate to highest audio frequency was 2.5. This had the advantage of simplifying the necessary filters at the demodulator, and accommodated an audio frequency band of 3200 cycles per second.

One advantage inherent in pulse modulation systems is the use of a high ratio of peak to average power for more efficient operation of the transmitter. In this application the pulse cycle was designed for an interval of 125 microseconds, and the pulse width was 10 microseconds. This resulted in a transmitter duty cycle of 8 percent, which would permit a peak power on the order of 12.5 times the average power used in conventional amplitude modulation systems. Theoretically the peak power could be increased still further, as the pulse duration is reduced, while maintaining a fixed average power out of the transmitter.

The major disadvantage of pulse modulation systems is the bandwidth requirement. The conventional amplitude and frequency modulation systems have a bandwidth determined by the audio side bands. Pulse system bandwidths are determined on a more critical basis. Once the pulse is modulated with the audio signal, the video stages following the modulator must have a frequency response determined by the rise time of the pulse.

For this equipment, the pulse was designed with a rise time of 0.5 microseconds, as measured from the 10 percent to 90 percent amplitude points. In order to pass this pulse without distorting the wave shape, a video amplifier with a frequency response of 1 megacycle would be required. In a similar manner the transmitter output bandwidth would be 2 megacycles. This could be confined to 1 megacycle if single side band transmission was utilized, but this in turn would require critical filtering at the transmitter.

Particularly in pulse amplitude modulation, the use of wider frequency bands do not improve signal-to-noise ratio. Theoretically, with a fixed average transmitter power and noise that has a uniform power density spectrum over the acceptance band, a greater frequency range affords no improvement in signal-to-noise ratio.

The theoretical minimum bandwidth is defined as that required for the audio side bands in a conventional modulation system. For the condition where peak instead of average power is utilized, whenever the bandwidth occupied by a pulse amplitude modulation system exceeds the theoretical minimum, the resulting signal-to-noise ratio is less. The wider the band, the smaller is the ratio. Thus, for a specified signal-to-noise ratio at the output of the system, more peak power is required as the band is widened. Howdver, although a wider band implies a larger signal power, other requirements are eased. This follows since the distortion tends to become unreasonably severe unless the occupied band is wide enough to accommodate the pulse rise time, which is considerably wider than the theoretical minimum.

There are several methods of pulse amplitude modulation available. These include single polarity pulses, double polarity pulses, single polarity flat-top pulses, and double polarity flat-top pulses. The first method, single polarity pulses was chosen for this application because of the relative simplicity of the modulator. The wave shapes of this form of modulation are demonstrated in the oscillograms included in this report. The greatest disadvantage of pulse amplitude modulation as compared to the other pulse modulation systems, concerns signal-to-noise ratio. The other types of pulse modulation involve a pulse of constant amplitude. Thus, as they pass through the receiver and pick up noise, the pulse can be treated by clipping and shaping at various stages to improve signal-to-noise ratio. The P. A. M. system in contrast has the best signal-to-noise ratio at the first stage of the receiver; the following stages can only cause deterioration, and there is no means of noise limiting applicable to the system.

EQUIPMENT AND TESTS

The transmitter and receiving equipment were completed in this period, and tests were made on a system basis.

Figure 1 represents a block diagram of the entire transmitter, which actually comprises two units, the modulator and the R.F. chassis.

Reference to the oscillographs as labeled, indicates the functioning of the stages in the system:

1) Point A - The positive pulse at one plate of the twin triode functioning as a free running multivibrator.

2) Point B - The other plate of the multivibrator. This is a negative pulse and is the one used as a source.

3) Point C - The output of the shaper. This was a well formed pulse. It has the positive polarity necessary to gate the following stage. The 0.5 microsecond rise time and the 10 microsecond pulse width were clearly demonstrated. This pulse was applied to the limiter grid of the modulator.

4) Point D - The audio signal applied to the quadrature grid of the modulator. This was provided by an audio oscillator, and functioned as the modulating signal.

5) Point E - The modulator output. The modulation

envelope was well represented. The pulse repetition rate was clearly indicated as 8000 cycles per second. The percentage of modulation was approximately 50 percent, but this could be readily adjusted by the separate bias controls on the two grids of the modulator. It was also possible to adjust these bias controls so that there would be no output unless a modulating signal was present. This in turn would result in no transmitter output unless a signal was to be communicated. This modulated pulse was essentially the output of the modulator chassis.

6) Point F - The output of the video amplifier as seen at the secondary of a pulse transformer. This was a pulse without audio modulation. It demonstrated pulse shape after passing through a transformer, and before being applied to the final R.F. amplifier.

7) Point G - The R. F. output of the buffer amplifier as seen at the grid of the power amplifier

without pulse applied. This demonstrated the R. F. frequency of the crystal oscillator.

8) Point G - Composite picture of the R.F. superimposed on the pulse. The pulse was not audio modulated in order to demonstrate more clearly the type signal applied to the grid of the power amplifier as grid modulation.

9) Point H - Output of transmitter as a radiated signal. In this oscillograph was summed up many of the features of pulse amplitude modulation, namely: Transmitter duty cycle, pulse repetition rate, modulating signal and percentage of modulation.

10) Point H - Enlargement of pulse shape at output, with R.F. modulation but without audio modulation for picture simplicity.

Figure 2 represents a block diagram of the entire receiver. This actually comprises three units; the first four stages of a commercial Hammarlund communications receiver, a small victoreen chassis that plugged into the last I.F. amplifier of the receiver, and a demodulator chassis.

The transmitted signal was received within the confines of a room; no test of range was undertaken. The signal was intelligible and was transmitted with a frequency response in accordance with the design, and with acceptable fidelity. Of major significance was the fact that the signal was received by an ordinary communications receiver as well as the specifically designed receiver unit. This clearly indicated that there was no security with a conventional type of pulse amplitude modulated system. Nevertheless, it is possible to combine systems for additional security, such as amplitude modulated pulsing of an F.M. transmitter.

11) Point I - Output of the pre-selector. At this point the effect of narrow bandwidths becomes apparent. The pulses have been greatly mis-shaped; but the general outline of pulse amplitude modulated R.F. is readily discernible. The second stage of the receiver, the converter, had so narrow a bandwidth that the I.F. output was barely recognizable as P.A.M. nevertheless, the intelligence of the signal was preserved.

12) Point J - Output of the cathode follower. These

remaining tests were made on a closed circuit basis, in order to better demonstrate the operation of the demodulator section. By this means, the mis-shaping of the receiver's narrow bandwidth R.F. stages, was avoided.

13) Point K - Output of a commercial low pass filter. The pulse was pretty well eliminated, leaving the audio signal as the intelligence. A low impedance input to the filter was required for proper operation. Thus a cathode follower stage preceded it.

14) Point L - Output of an M-derived constant-K low pass filter. This was designed as an infinite impedance device for the pulse repetition rate frequency. The pulse essentially was eliminated at this point.

15) Point M - The audio signal input to an external loudspeaker. The sinusoidal wave shape is of particular interest.

Figures 3 and 4 are schematic diagrams of the R.F. chassis and the demodulator chassis. They are included because significant modifications have been made in their original design as represented in progress report No. 1.

CONCLUSIONS AND FUTURE PLANS

A pulse amplitude modulated transmitter and receiver was designed and tested on a system basis. The received signal was entirely intelligible.

It was noted that a commercial communications receiver could receive the transmitted signal adequately. This negates the possibility of security in communications with a conventional pulse amplitude modulated system.

The requirement of large bandwidth for pulse systems was demonstrated. The efficiency of utilizing peak pulsed power as against large average power of conventional modulation systems was indicated.

The signal-to-noise ratio of the signal, as it appears at the input to the receiver, could not be improved as it passed through the receiver. This disadvantage is not true of other pulse modulation systems.

Oscillographs of the signal were taken at various stages of the transmitter and receiver and the wave forms demonstrated.

It is planned to design a system of pulse position modulation, and investigate its characteristics. It will be compared to the pulse amplitude modulated system already tested.

A transmitter will be designed to operate at 50 megacycles with wide bandwidth capabilities. This will be used as the standard for a comparison of all pulse modulation systems.

A wide band receiver to operate in conjunction with the 50 megacycle transmitter will be designed.

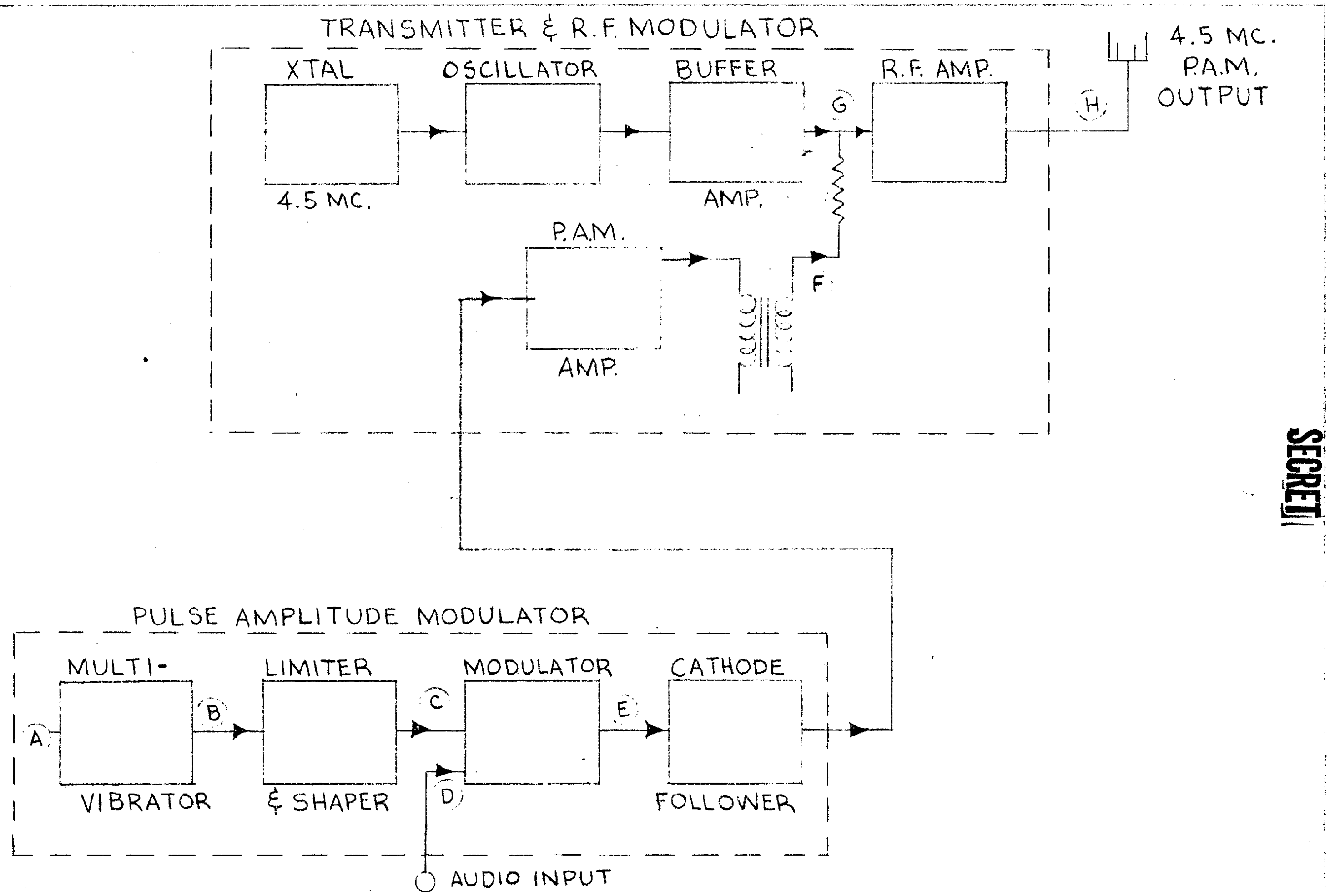

FIG. I - PULSE AMPLITUDE MODULATED TRANSMITTER

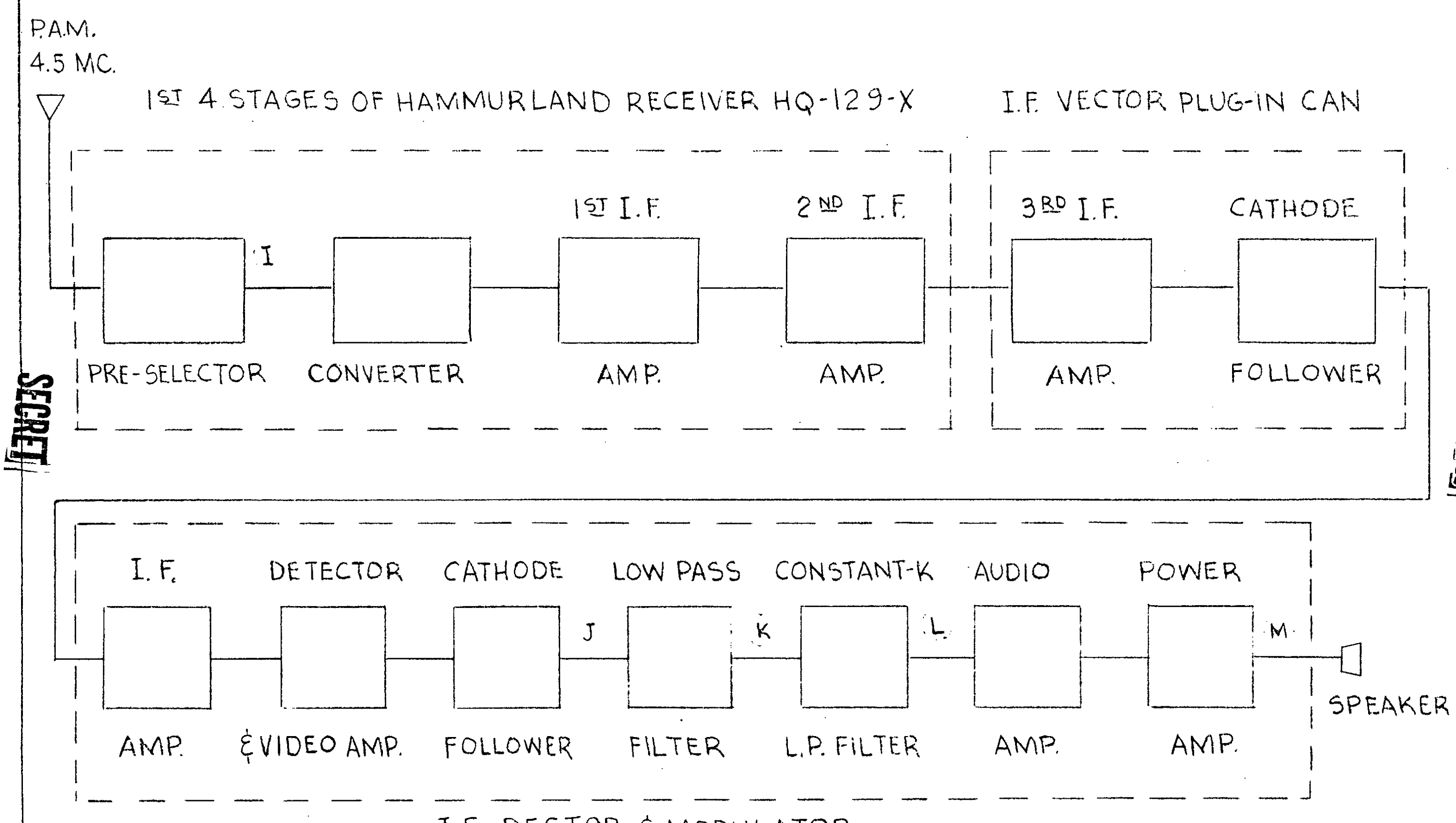

FIG. 2 PULSE AMPLITUDE MODULATED RECEIVER

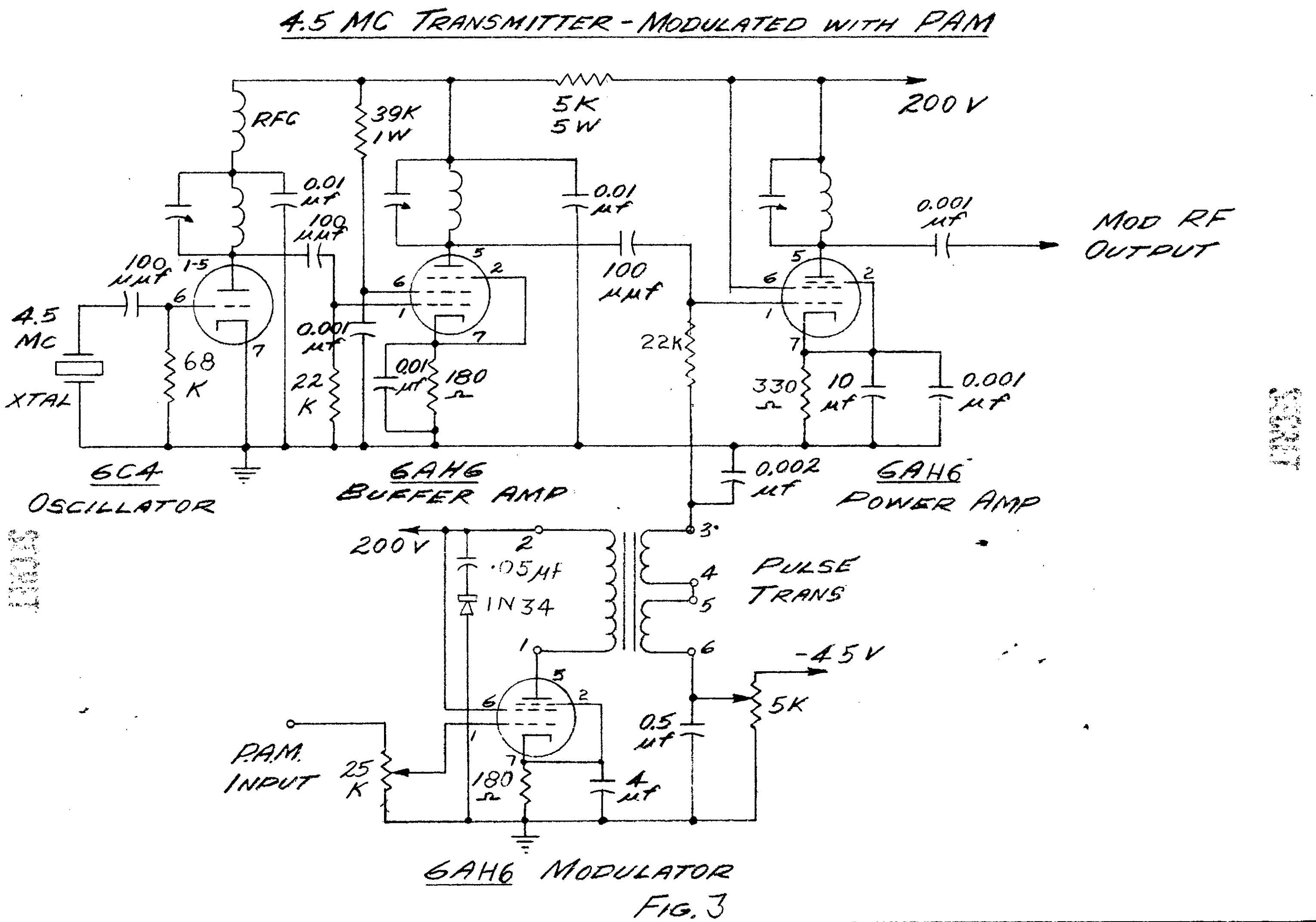

FIG. 3

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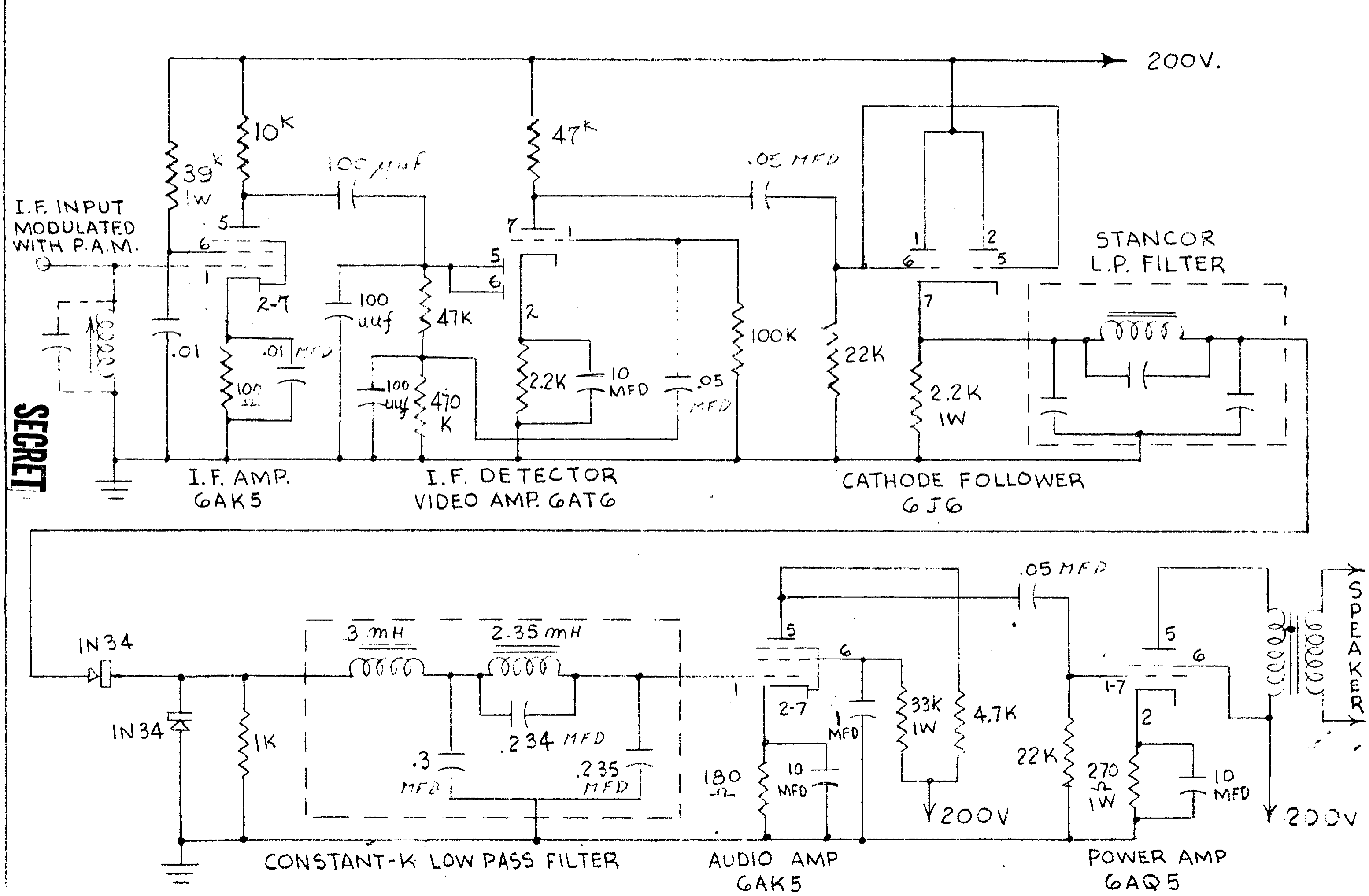
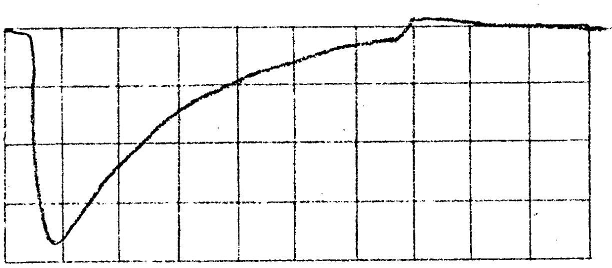
FIG. 4 - P.A.M. DEMODULATOR

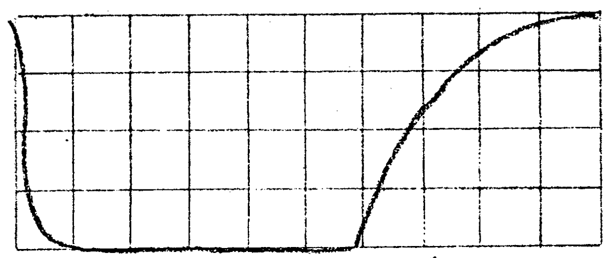


1



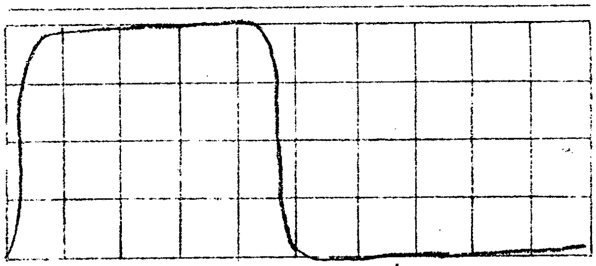
SENSITIVITY - V/CM 21
SWEEP - μ SEC/CM 1.0
SIGNAL Point A

2



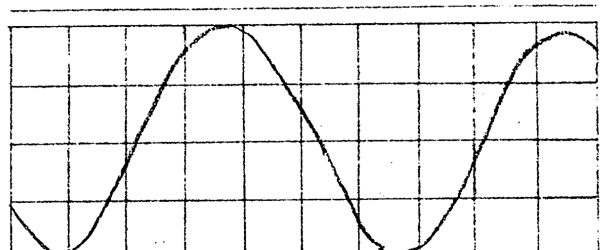
SENSITIVITY - V/CM 3.25
SWEEP - μ SEC/CM 1.0
SIGNAL Point B

3



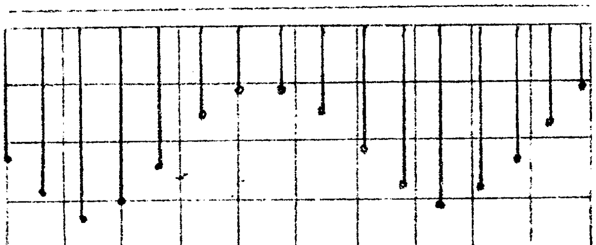
SENSITIVITY - V/CM 1.35
SWEEP - μ SEC/CM 20
SIGNAL Point C

4



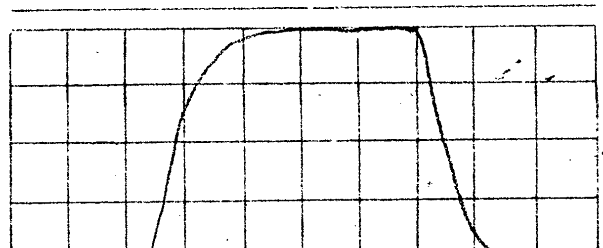
SENSITIVITY - V/CM 0.78
SWEEP - μ SEC/CM 200
SIGNAL Point D

5



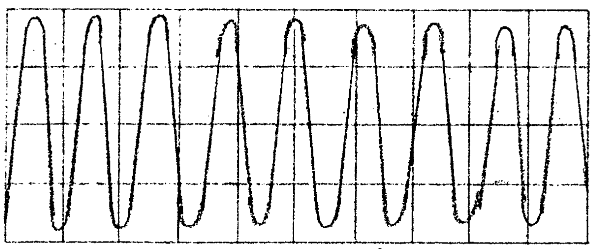
SENSITIVITY - V/CM 0.3
SWEEP - μ SEC/CM 200
SIGNAL Point E

6



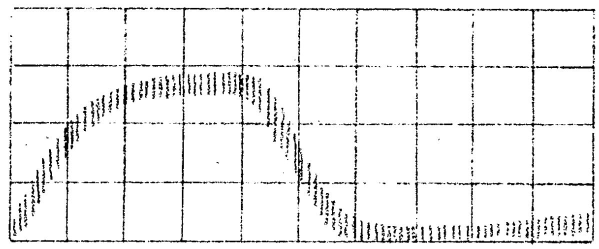
SENSITIVITY - V/CM 0.6
SWEEP - μ SEC/CM 2
SIGNAL Point F, No Audio

7



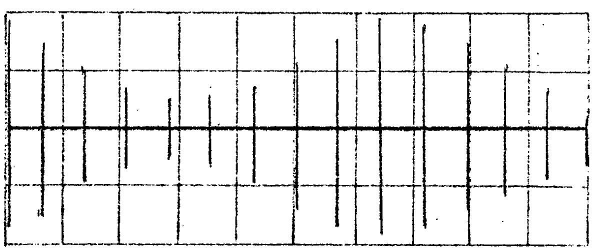
SENSITIVITY - V/CM 4.8
SWEEP - μ SEC/CM 0.2
SIGNAL Point G, R.F. Only

8



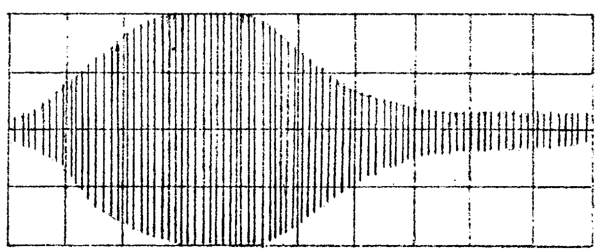
SENSITIVITY - V/CM 1.3
SWEEP - μ SEC/CM 2
SIGNAL Point G, No Audio

9



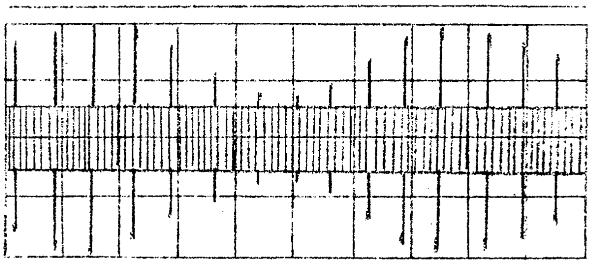
SENSITIVITY - V/CM 5.25
SWEEP - μ SEC/CM 200
SIGNAL Point H

10



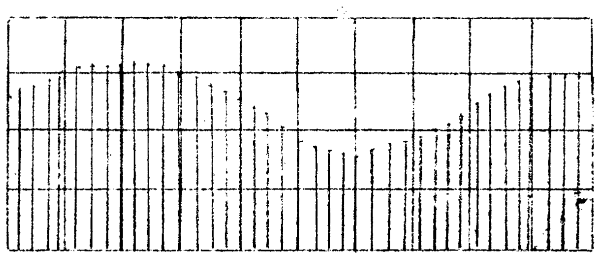
SENSITIVITY - V/CM 5.25
SWEEP - μ SEC/CM 2
SIGNAL Point H, No Audio

11



SENSITIVITY - V/CM 0.375
SWEEP - μ SEC/CM 200
SIGNAL Point I

12



SENSITIVITY - V/CM 2.75
SWEEP - μ SEC/CM 540
SIGNAL Point J, Closed System

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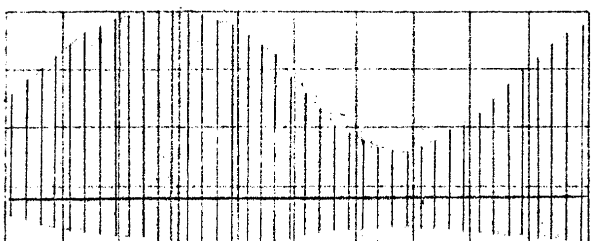
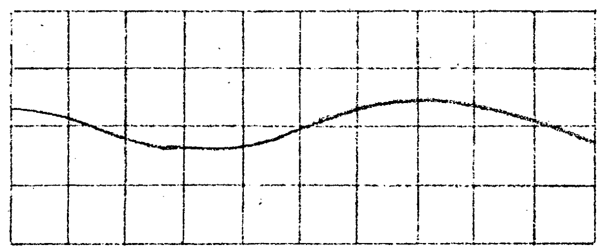
13



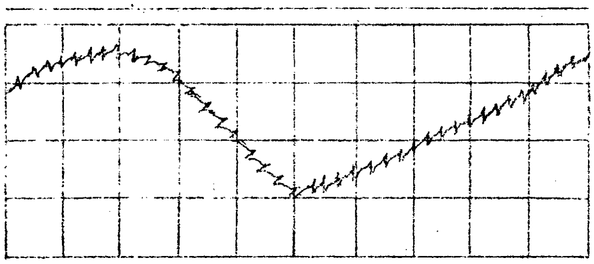
SENSITIVITY - V/CM 0.42
SWEEP - μ SEC/CM 540
SIGNAL Point K, Closed System

14



SENSITIVITY - V/CM 0.03
SWEEP - μ SEC/CM 540
SIGNAL Point L, Closed System

15



SENSITIVITY - V/CM 0.3
SWEEP - μ SEC/CM 540
SIGNAL Point M, Closed System

SENSITIVITY - V/CM
SWEEP - μ SEC/CM
SIGNAL

SENSITIVITY - V/CM
SWEEP - μ SEC/CM
SIGNAL

SENSITIVITY - V/CM
SWEEP - μ SEC/CM
SIGNAL

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